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PHYTOTOXICOLOGY SURVEY OF MERCURY CONCENTRATIONS: LAMBTON THERMAL GENERATING STATION

LAMBTON, 1990-1991

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PHYTOXICOLOGY SURVEY OF MERCURY CONCENTRATIONS
LAMBTON THERMAL GENERATING STATION, LAMBTON 1990-1991

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Standards Development Branch

Abstract

Phytotoxicology Survey of Mercury Concentrations: Lambton Thermal Generating Station - Lambton 1990 - 91

Soil and tree foliage were collected from 23 sites in the vicinity of the Lambton Thermal Generating Station in 1990 and 1991 and analyzed for total mercury, lead, cadmium, and zinc. The soil and vegetation metal concentrations were with in the range considered normal for a rural environment. Furthermore, there were no concentration gradients for any of the metals with distance or direction from the generating station.

Table of Contents

Abstract 1

Table of Contents 2

List of Tables 3

List of Figures 4

1.0 Introduction 5

2.0 Methods 6

3.0 Results and Discussion 6

- 3.1 Mercury in Soil 6
- 3.2 Lead, Cadmium and Zinc in Soil 7
- 3.3 Mercury in Silver Maple Foliage 7
- 3.4 Lead Cadmium and Zinc in Silver Maple Foliage 8

4.0 Summary 8

References 8

Derivation and Significance of the MOEE Phytotoxicology "Upper Limits of Normal" Contaminant Guidelines. 19

List of Tables

1: Mercury concentrations in Soil (0-5 cm depth) collected in the viciniiy of Lambton Thermal Generating Station on Aug. 21, 1990 May 22, 1991 and Aug. 27, 1991 (units in ug/g dry wt.). 10

2: Lead concentrations in soil (0-5 cm depth) collected in the vicinity of Lambton Thermal Generating Station on August. 21, 1990, and Aug. 27, 1991 (units in ug/g dry wt.). 11

3: Cadmium concentrations in soil (0-5 cm depth) collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990 and Aug. 27, 1991 (units in ug/g dry wt.). 12

4: Zinc concentrations in soil (0-5 cm depth) collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990, and Aug. 27, 1991 (units in ug/g dry wt.). 13

5: Mercury concentrations in maple foliage collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990 and Aug. 27, 1991 (units in ug/g dry wt.). 14

6: Lead concentrations in maple foliage collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990, and Aug. 27, 1991 (units in ug/g dry wt.). 15

7: Cadmium concentrations in maple foliage collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990, and Aug. 27, 1991 (units in ug/g dry wt.). 16

8: Zinc concentrations in maple foliage collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990 and Aug. 27, 1991 (units in ug/g dry wt.). 17

List of Figures

1: Locations of sites established in investigate mercury concentrations in soil and silver maple foliage in the vicinity of the Lambton Thermal Generating Station (1990 - 1991) 18

Phytotoxicology Survey of Mercury Concentrations: Lambton Thermal Generating Station - Lambton
1990-1991

1.0 Introduction:

Trace inorganic elements, such as arsenic (As), copper (Cu), fluoride (F), lead (Pb), nickel (Ni), mercury (Hg), selenium (Se) and zinc (Zn) are present in coal and can be emitted to the atmosphere, along with SO_2 , NOx and VOCs, during combustion in coal-fired stations (7). Emission controls, such as wet scrubbers, can remove 30 to 90% of trace metals and particulates from flue gas; with the exception of mercury. Unlike other metals, mercury remains partially in a gaseous form, even during the scrubbing process (8). As much as 90% of the mercury present in coal utilized in a coal-fired, electrical power generating plant can end up in stack emissions (1). Approximately 0.32 g of mercury is emitted to the atmosphere for each ton of coal combusted (8).

At present, Ontario Hydro's Lambton Thermal Generating Station (LTGS) near Sarnia, Ontario, burns pulverized bituminous coal at rates up to 160 tonnes/h for each of the four generating units at the facility (6). Each unit normally operates between a minimum load of 120 MW and a maximum load of approximately 500 MW and the estimated volume of flue gas released from each unit is 8216 m^3 per tonne of coal burned (6). Therefore, mercury present in emissions from the power plant stacks could be accummulating in soil and vegetation in the vicinity of LTGS.

Since 1969, the Phytotoxicology Section, of the Hazardous Contaminants Branch of the Ontario Ministry of Environment and Energy, has conducted various vegetation surveillance programs in the Courtright-Sombra area of Ontario. During that initial year, a survey was set up around the LTGS to investigate possible injury to silver maple trees and grasses due to emissions of sulfur dioxide and fluorides from the Lambton facility, as well as the two Detroit Edison thermal generating plants situated on the Michigan side of the St. Clair River, across from the Lambton generating station. This survey was conducted each year by the Phytotoxicology Section until as recently as 1986. Mercury analysis was not included in these earlier surveys.

In that same year (1969), a second survey was intiated to investigate fluoride emissions from the Canadian Industries Ltd. Lambton Works, which produced fertilizers. This plant is located approximately two kilometers south-east of the LTGS. Several of the sites established for this survey are in the vicinity of the generating station.

The present survey (1990 and 1991) was carried out to determine if mercury concentrations in soil and/or silver maple foliage are elevated in the vicinity of the LTGS. Sites for the present study were selected from those already established in the original LTGS survey and the CIL survey.

Soil samples were collected on August 21, 1990, again on May 22, 1991, and finally on August 27, 1991, in an attempt to uncover possible seasonal patterns in atmospheric depostion and accumulation of mercury in surface soil. Seasonal patterns of mercury accumulation have been reported in the literature (3) which suggested that mercury accumulated in winter snow and cool spring soil but volatilized and was lost from the soil as the soil warmed during the summer months.

2.0 Methods:

Twenty-three sites were chosen from the historic LTGS and CIL surveys for this study. Site locations were selected on concentric circles of increasing distance (1km to 12 km) from the LTGS (refer to Figure 1). An "L" designates sites which were chosen from the original LTGS survey. The three sites designated with a "C" were selected from the CIL survey.

At each site, duplicate samples of soil (0-5 cm) and silver maple foliage were collected on August 21, 1990. The samples were processed in the Phytotoxicology laboratory prior to submission to the MOEE laboratory at 125 Resources Rd. in Rexdale, for mercury, cadmium, lead and zinc analysis. Duplicate soil samples (0-5 cm) were also sampled from these sites the following spring, on May 22, 1991, processed and submitted for analysis of mercury only. Silver maple foliage was not sampled at this time.

As in the previous year, duplicate soil samples (0-5 cm) and silver maple foliage samples were again collected on August 27, 1991, processed by the Phytotoxicology laboratory and submitted to the MOEE laboratory for analysis of mercury, cadmium, lead and zinc.

3.0 Results and Discussion:

3.1 Mercury in Soil:

Volatile mercury deposited from the atmosphere, mainly in the form of Hg°, is easily absorbed by soil organic matter and can accumulate in surface soils over time (9). Mercury concentrations in soil (0-5 cm depth) collected on the three dates are given in Table 1.

In this study, spring soil mercury concentrations (collected May 22, 1991) were slightly higher at seventeen of the twenty-three sites than either of the two August collections,which suggests some seasonal differences may in fact exist. However, soil mercury levels at all but one of the sites were well below the rural Upper Limit of Normal (ULN) guideline for mercury (0.15 ppm) during the three collection dates (refer to Appendix). There was no significant relationship between mercury levels in soil and distance from the thermal generating station. Soil concentration contour maps for mercury were not produced because the soil mercury concentrations did not differ significantly from site to site. Contour mapping would be meaningless in this case.

Although the mercury concentration in soil (0.38 ppm) collected from Site L27 on August 21, 1990 was higher than the rural ULN (0.15 ppm), this site is located 9 km north of the LTGS and is within the city limits of Sarnia. The mercury concentration of soil collected at Site L27 did not exceed the urban mercury ULN (0.5 ppm). Soil sampled at this same site in May 1991, and again in August, 1991, contained only 0.08 ppm mercury on both occasions, which is more consistent with soil mercury levels that occurred at the other sampling sites in the study. These data indicate that soil mercury concentrations in the vicinity of the LTGS are within the normal background range for rural areas. Even the highest mercury concentration did not exceed the urban ULN.

The results of a study conducted around the Four Corners Power plant in New Mexico during the late 1970's, support the lack of elevated mercury concentrations in soil in the vicinity of the LTGS (2). Even though the Four Corners plant emitted 1-2% of all the mercury released by U.S. coal-fired utilities at that time, the soil residue levels near the plant were low and did not differ statistically from background. The authors concluded that while the fate of the mercury emitted by the thermal plant was not known, it was not accumulating in the soil surrounding the thermal plant (2).

3.2. Lead, Cadmium and Zinc in Soil:

Additional analyses were performed to determine if cadmium, lead and zinc, which are common contaminants of urbanization, were elevated in the study area. Cadmium and lead are of particular concern to human health and zinc can be phytotoxic if elevated in soil. Soil concentrations for lead, cadmium and zinc in soils sampled at the selected sites on August 21, 1990, and again on August 27, 1991, are given in Tables 2,3 and 4, respectively. These were the same soil samples that were collected for mercury analysis. At all the survey sites, soil concentrations of these three metals were below their respective rural ULNs. Also, there was no relationship between soil metal concentrations and distance and direction from the LTGS.

3.3 Mercury in Silver Maple Foliage:

Root uptake of mercury compounds from soil is usually not significant due to selective physiological barriers at the root epidermis (4). However, atmospheric mercury species are readily absorbed through stomates of leaves and stems in direct proportion to ambient air concentrations (5). Results of controlled greenhouse and field studies conducted by staff of the Hazardous Contaminants Branch, Phytotoxicology Section indicate that over 90% of mercury uptake by test plants (i.e. lettuce, beets, radish and carrot) is through foliage. Therefore, elevated mercury concentrations in silver maple foliage would suggest that mercury in the atmosphere was the likely source of mercury contamination in the foliage.

Mercury concentrations in unwashed silver maple foliage collected on August 21, 1990 or August 27, 1991 are shown in Table 5. On both sampling dates, only trace amounts of mercury were present in the maple foliage. Neither the rural nor urban ULNs were exceeded. Curiously, the highest foliar mercury concentration occurred at Site L27 in August 1990, which was the site and year of the anomalously elevated soil mercury concentration. Therefore, even though ambient mercury is the main avenue of mercury uptake by plants, in the absence of an ambient source, uptake of soil mercury will contribute to foliar concentrations.

There was no significant relationship between mercury concentrations in silver maple foliage and distance from the LTGS. These data suggest that levels of atmospheric mercury in the vicinity of the LTGS are not above normal background levels.

3.4 Lead, Cadmium and Zinc in Silver Maple Foliage:

Concentrations of lead, cadmium and zinc in unwashed silver maple foliage are given in Tables 6 to 8. These were the same unwashed foliage samples that were collected for mercury analysis. At all stations, the foliar concentrations of cadmium, lead and zinc were below their respective rural ULN. There was no relationship between foliar metal concentrations and distance and direction from LTGS.

4.0 Summary:

Mercury concentrations in soil and silver maple foliage collected in 1990 and again 1991, in the vicinity of the LTGS were within the range considered normal for rural areas in Ontario. Mercury levels were not elevated in soil or foliage of silver maple trees located in the vicinity of the Lambton facility.

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Table 1: Mercury concentrations in soil (0-5 cm depth) collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990 May 22, 1991 and Aug. 27, 1991 (units in ug/g dry wt.).

Site No.	Distance/ Direction from LGS	UTM Easterly (plus zone)	UTM Northerly	Hg concen. Aug. 1990*	Hg concen. May 1991*	Hg concen. Aug. 1991*
L1	1 km NE	17 381125	4740225	0.07	0.10	0.08
L2	2 km NE	17 382318	4741100	0.02T	0.04T	0.05T
L3	3 km NE	17 383880	4742100	0.04T	0.07	0.04T
L22	3.5 km NE	17 383589	4743678	0.01T	0.04T	0.03T
L4	4 km NE	17 385416	4746360	0.06	0.05T	0.04T
L24	5 km N	17 380992	4750725	0.03T	0.05T	0.04T
L5	6 km NE	17 387368	4751708	0.01T	0.04T	0.03T
L27	9 km N	17 386652	4757448	0.38	0.08	0.08
L30	10 km NE	17 395916	4748531	0.02T	0.04T	0.03T
L29	12 km NE	17 393861	4754504	0.04T	0.06	0.05T
L6	1 km E	17 381600	4738775	0.05T	0.06	0.05T
L7	2 km E	17 383289	4738315	0.05T	0.08	0.03T
L21	4 km E	17 385950	4740750	0.04T	0.06	0.04T
L9	5 km E	17 387350	4738125	0.03T	0.05T	0.03T
L31	10 km E	17 395040	4738580	0.02T	0.06	0.04T
L11	1 km SE	17 381125	4738408	0.04T	0.02T	0.02T
L12	2 km SE	17 381958	4736550	0.02T	0.05T	0.02T
C12	5 km S	17 384030	4732810	0.03T	0.04T	0.03T
C8	6 km SE	17 386290	4734270	0.03T	0.05T	0.04T
C13	6 km S	17 383000	4730120	0.02T	0.04T	0.03T
L34	10 km S	17 377100	4723570	0.03T	0.04T	0.04T
L32	12 km SE	17 395344	4730980	0.03T	0.09	0.05T
L33	12 km S	17 388012	4723092	0.05T	0.05T	0.06
Upper Limit of Normal for rural/urban soils				0.15 / 0.5	0.15 / 0.5	0.15 / 0.5

* Mean of two sample replicates T= trace amount, interpret with caution.

Table 2: Lead concentrations in soil (0-5 cm depth) collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990, and Aug. 27, 1991 (units in ug/g dry wt.).

Site No.	Distance/ Direction from LGS	UTM Easterly (plus zone)	UTM Northerly	Pb concen. Aug. 1990*	Pb concen. Aug.1991*
L1	1 km NE	17 381125	4740225	29	18
L2	2 km NE	17 382318	4741100	17	31
L3	3 km NE	17 383880	4742100	23	16
L22	3.5 km NE	17 383589	4743678	22	14
L4	4 km NE	17 385416	4746360	23	28
L24	5 km N	17 380992	4750725	62	70
L5	6 km NE	17 387368	4751708	18	18
L27	9 km N	17 386652	4757448	35	30
L30	10 km NE	17 395916	4748531	16	15
L29	12 km NE	17 393861	4754504	22	16
L6	1 km E	17 381600	4738775	29	15
L7	2 km E	17 383289	4738315	32	23
L21	4 km E	17 385950	4740750	28	17
L9	5 km E	17 387350	4738125	19	13
L31	10 km E	17 395040	4738580	38	27
L11	1 km SE	17 381125	4738408	15	12
L12	2 km SE	17 381958	4736550	18	13
C12	5 km S	17 384030	4732810	28	24
C8	6 km SE	17 386290	4734270	23	20
C13	6 km S	17 383000	4730120	25	20
L34	10 km S	17 377100	4723570	36	32
L32	12 km SE	17 395344	4730980	38	46
L33	12 km S	17 388012	4723092	30	25
Upper Limit of Normal for rural/urban soils				150/500	150/500

* Mean of two sample replicates

Table 3: Cadmium concentrations in soil (0-5 cm depth) collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990, and Aug. 27, 1991 (units in ug/g dry wt.).

Site No.	Distance/ Direction from LGS	UTM Easterly (plus zone)	UTM Northerly	Cd concen. Aug. 1990*	Cd concen. Aug.1991*
L1	1 km NE	17 381125	4740225	0.89	2
L2	2 km NE	17 382318	4741100	0.62	1.5
L3	3 km NE	17 383880	4742100	0.93	0.83
L22	3.5 km NE	17 383589	4743678	0.88	1.1
L4	4 km NE	17 385416	4746360	0.60	1.2
L24	5 km N	17 380992	4750725	0.24	0.82
L5	6 km NE	17 387368	4751708	0.86	1.25
L27	9 km N	17 386652	4757448	0.88	0.92
L30	10 km NE	17 395916	4748531	0.39	0.44
L29	12 km NE	17 393861	4754504	0.28	1.2
L6	1 km E	17 381600	4738775	0.35	1.45
L7	2 km E	17 383289	4738315	0.04T	1.2
L21	4 km E	17 385950	4740750	0.34	0.54
L9	5 km E	17 387350	4738125	0.78	1.17
L31	10 km E	17 395040	4738580	0.26	0.51
L11	1 km SE	17 381125	4738408	0.66	1.5
L12	2 km SE	17 381958	4736550	0.09T	1.2
C12	5 km S	17 384030	4732810	0.54	1.35
C8	6 km SE	17 386290	4734270	0.39	2.25
C13	6 km S	17 383000	4730120	0.62	1.8
L34	10 km S	17 377100	4723570	0.34	1.06
L32	12 km SE	17 395344	4730980	0.1T	0.51
L33	12 km S	17 388012	4723092	0.05T	0.71
Upper Limit of Normal for rural/urban soils				3 / 4	3 / 4

* Mean of two sample replicates T = trace amount, interpret with caution

Table 4: Zinc concentrations in soil (0-5 cm depth) collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990, and Aug. 27, 1991 (units in ug/g dry wt.).

Site No.	Distance/ Direction from LGS	UTM Easterly (plus zone)	UTM Northerly	Zn concen. Aug. 1990*	Zn concen. Aug.1991*
L1	1 km NE	17 381125	4740225	125	110
L2	2 km NE	17 382318	4741100	98	220
L3	3 km NE	17 383880	4742100	95	64
L22	3.5 km NE	17 383589	4743678	64	72
L4	4 km NE	17 385416	4746360	86	82
L24	5 km N	17 380992	4750725	61	56
L5	6 km NE	17 387368	4751708	69	67
L27	9 km N	17 386652	4757448	120	110
L30	10 km NE	17 395916	4748531	64	56
L29	12 km NE	17 393861	4754504	71	67
L6	1 km E	17 381600	4738775	102	80
L7	2 km E	17 383289	4738315	91	79
L21	4 km E	17 385950	4740750	74	41
L9	5 km E	17 387350	4738125	68	61
L31	10 km E	17 395040	4738580	95	85
L11	1 km SE	17 381125	4738408	69	72
L12	2 km SE	17 381958	4736550	85	80
C12	5 km S	17 384030	4732810	105	92
C8	6 km SE	17 386290	4734270	115	110
C13	6 km S	17 383000	4730120	99	90
L34	10 km S	17 377100	4723570	87	120
L32	12 km SE	17 395344	4730980	120	105
L33	12 km S	17 388012	4723092	100	92
Upper Limit of Normal for rural/urban soils				500	500

* Mean of two sample replicates

Table 5: Mercury concentrations in maple foliage collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990, and Aug. 27, 1991 (units in ug/g dry wt.).

Site No.	Distance/ Direction from LGS	UTM Easterly (plus zone)	UTM Northerly	Hg concen. Aug. 1990*	Hg concen. Aug.1991*
L1	1 km NE	17 381125	4740225	0.03T	0.03T
L2	2 km NE	17 382318	4741100	0.05T	0.04T
L3	3 km NE	17 383880	4742100	0.0T	0.03T
L22	3.5 km NE	17 383589	4743678	0.03T	0.02T
L4	4 km NE	17 385416	4746360	0.03T	0.03T
L24	5 km N	17 380992	4750725	0.04T	0.03T
L5	6 km NE	17 387368	4751708	0.06T	0.03T
L27	9 km N	17 386652	4757448	0.07T	0.03T
L30	10 km NE	17 395916	4748531	0.04T	0.03T
L29	12 km NE	17 393861	4754504	0.01T	0.02T
L6	1 km E	17 381600	4738775	0.04T	0.04T
L7	2 km E	17 383289	4738315	0.04T	0.03T
L21	4 km E	17 385950	4740750	0.04T	0.02T
L9	5 km E	17 387350	4738125	0.06T	0.03T
L31	10 km E	17 395040	4738580	0.03T	0.02T
L11	1 km SE	17 381125	4738408	0.04T	0.04T
L12	2 km SE	17 381958	4736550	0.04T	0.03T
C12	5 km S	17 384030	4732810	0.05T	0.05T
C8	6 km SE	17 386290	4734270	0.03T	0.04T
C13	6 km S	17 383000	4730120	0.05T	0.03T
L34	10 km S	17 377100	4723570	0.05T	0.04T
L32	12 km SE	17 395344	4730980	0.03T	0.03T
L33	12 km S	17 388012	4723092	0.04T	0.04T
Upper Limit of Normal for rural/urban foliage				0.1 / 0.3	0.1 / 0.3

* Mean of two sample replicates T= trace amount, interpret with caution.

Table 6: Lead concentrations in maple foliage collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990, and Aug. 27, 1991 (units in ug/g dry wt.).

Site No.	Distance/ Direction from LGS	UTM Easterly (plus zone)	UTM Northerly	Pb concen. Aug. 1990*	Pb concen. Aug.1991*
L1	1 km NE	17 381125	4740225	DL	0.7T
L2	2 km NE	17 382318	4741100	1.7	1.3T
L3	3 km NE	17 383880	4742100	1.0T	1.5T
L22	3.5 km NE	17 383589	4743678	2.5	1.7T
L4	4 km NE	17 385416	4746360	2.8	1.4T
L24	5 km N	17 380992	4750725	3.2	6.6
L5	6 km NE	17 387368	4751708	1.5T	2.1T
L27	9 km N	17 386652	4757448	DL	1.6T
L30	10 km NE	17 395916	4748531	2.6	1.2T
L29	12 km NE	17 393861	4754504	1.3T	1.1T
L6	1 km E	17 381600	4738775	DL	1.0T
L7	2 km E	17 383289	4738315	0.9T	1.2T
L21	4 km E	17 385950	4740750	1.6T	1.7T
L9	5 km E	17 387350	4738125	1.1T	0.9T
L31	10 km E	17 395040	4738580	1.0T	1.2T
L11	1 km SE	17 381125	4738408	1.3T	1.3T
L12	2 km SE	17 381958	4736550	2.1	0.4T
C12	5 km S	17 384030	4732810	2.2	2.7
C8	6 km SE	17 386290	4734270	0.9T	2.2T
C13	6 km S	17 383000	4730120	1.6T	1.5T
L34	10 km S	17 377100	4723570	2.6	2.9
L32	12 km SE	17 395344	4730980	0.8T	0.6T
L33	12 km S	17 388012	4723092	1.8	1.1T
Upper Limit of Normal for rural/urban foliage				30 / 60	30 / 60

* Mean of two sample replicates T = trace amount, interpret with caution DL = below analytical detection limit

Table 7: Cadmium concentrations in maple foliage collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990, and Aug. 27, 1991 (units in ug/g dry wt.).

Site No.	Distance/ Direction from LGS	UTM Easterly (plus zone)	UTM Northerly	Cd concen. Aug. 1990*	Cd concen. Aug.1991*
L1	1 km NE	17 381125	4740225	0.12T	DL
L2	2 km NE	17 382318	4741100	0.18T	0.1T
L3	3 km NE	17 383880	4742100	0.29T	0.11T
L22	3.5 km NE	17 383589	4743678	0.22T	DL
L4	4 km NE	17 385416	4746360	0.32T	DL
L24	5 km N	17 380992	4750725	0.14T	0.15T
L5	6 km NE	17 387368	4751708	DL	0.15T
L27	9 km N	17 386652	4757448	DL	0.15T
L30	10 km NE	17 395916	4748531	0.21T	DL
L29	12 km NE	17 393861	4754504	DL	0.18T
L6	1 km E	17 381600	4738775	DL	DL
L7	2 km E	17 383289	4738315	DL	DL
L21	4 km E	17 385950	4740750	0.14T	DL
L9	5 km E	17 387350	4738125	0.14T	DL
L31	10 km E	17 395040	4738580	0.11T	0.12T
L11	1 km SE	17 381125	4738408	0.17T	0.2T
L12	2 km SE	17 381958	4736550	0.18T	0.1T
C12	5 km S	17 384030	4732810	DL	0.18T
C8	6 km SE	17 386290	4734270	DL	0.17T
C13	6 km S	17 383000	4730120	0.26T	0.18T
L34	10 km S	17 377100	4723570	DL	DL
L32	12 km SE	17 395344	4730980	DL	DL
L33	12 km S	17 388012	4723092	0.18T	DL
Upper Limit of Normal for rural/urban foliage				1 / 2	1 / 2

* Mean of two sample replicates T = trace amount, interpret with caution DL = below analytical detection limit.

Table 8: Zinc concentrations in maple foliage collected in the vicinity of Lambton Thermal Generating Station on Aug. 21, 1990, and Aug. 27, 1991 (units in ug/g dry wt.).

Site No.	Distance/ Direction from LGS	UTM Easterly (plus zone)	UTM Northerly	Zn concen. Aug. 1990*	Zn concen. Aug.1991*
L1	1 km NE	17 381125	4740225	39	34
L2	2 km NE	17 382318	4741100	27	23
L3	3 km NE	17 383880	4742100	27	21
L22	3.5 km NE	17 383589	4743678	32	23
L4	4 km NE	17 385416	4746360	33	24
L24	5 km N	17 380992	4750725	39	31
L5	6 km NE	17 387368	4751708	31	32
L27	9 km N	17 386652	4757448	34	36
L30	10 km NE	17 395916	4748531	37	40
L29	12 km NE	17 393861	4754504	37	21
L6	1 km E	17 381600	4738775	50	40
L7	2 km E	17 383289	4738315	75	65
L21	4 km E	17 385950	4740750	29	24
L9	5 km E	17 387350	4738125	24	22
L31	10 km E	17 395040	4738580	23	17
L11	1 km SE	17 381125	4738408	33	31
L12	2 km SE	17 381958	4736550	34	36
C12	5 km S	17 384030	4732810	30	24
C8	6 km SE	17 386290	4734270	39	31
C13	6 km S	17 383000	4730120	46	25
L34	10 km S	17 377100	4723570	60	47
L32	12 km SE	17 395344	4730980	29	28
L33	12 km S	17 388012	4723092	34	30
Upper Limit of Normal for rural/urban foliage				250	250

* Mean of two sample replicates